Monitoring The Ionosphere Using A Global GPS Network: Validation and Applications

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Abstract:

A globally distributed network of dual-frequency GPS receivers currently exists and enables the monitoring of ionospheric total electron content(TEC) on global scales. Global maps of TEC useful for calibrating propagation delays, or monitoring the solar-terrestrial environment, can be produced continuously using this operational network. Potential applications include global wide-area differential GPS (WADGPS) systems, single-frequency satellite ocean altimetry missions, monitoring and prediction of space weather conditions, corrections for single-frequency satellite tracking stations and astronomical observatories, regional ionospheric studies, and long-term monitoring of environmental change. The rapidly growing international GPS network currently contains 80+ globally-distributed sites, with some notable gaps in the equatorial region and southern latitudes being filled in during the past year. In addition to this GPS resource, the TEC data set can be augmented using other dual-frequency tracking systems, such as the DORIS and PRARE systems.

By using spatial interpolation and temporal smoothing between the TEC measurements, combined with model information from a climatological ionospheric model, we are able to produce global ionospheric maps (GIM) of vertical TEC every 15 minutes. The instrumental biases in the GPS receivers and satellite transmitters are also estimated simultaneously. A Kalman-type filter optimally combines the absolute and relative TEC measurements with model information and also yields a formal error map.

Several improvements to GIM have recently been implemented: an improved parameterization of the TEC grid, optimized stochastic estimation strategy, several new strategies for constraining the maps using model information, and a ml-time capability. The accuracy of the global maps has been extensively validated by comparisons to independent ionospheric measurements: vertical TEC data from the dual-frequency altimeter on TOPEX, slant TEC data from a wide-spectrum instrument on the ALEXIS satellite, Faraday rotation, and ionosonde. Current comparisons indicate that the GPS-driven maps are accurate globally to 3-10 TECU (10^{16} el/m^2) and enable a continuous, global ionospheric specification which is more accurate than any of the existing empirical models. An extension of GIM to the 3-D ionosphere, in which the GPS data are used to optimally adjust model-derived electron density profiles, is also currently under development.